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MASSACHUSETTS COASTAL COMMERCIAL LOBSTER TRAP SAMPLING PROGRAM MAY-NOVEMBER, 1993

Bruce T. Estrella
and
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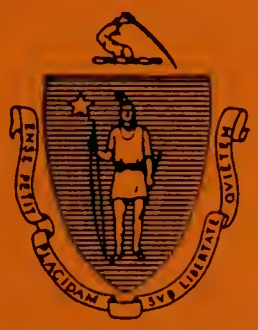

COMMONWEALTH OF MASSACHUSETTS
Division of Marine Fisheries
Philip G. Coates, Director

Department of Fisheries, Wildlife and
Environmental Law Enforcement
John C. Phillips, Commissioner

Executive Office of Environmental Affairs
Trudy Coxe, Secretary

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ABSTRACT

This is the Massachusetts Division of Marine Fisheries thirteenth annual assessment of the status of the American lobster resource in Massachusetts coastal waters. During the period of May through November, 1993, eighty-five sampling trips were made aboard commercial lobster vessels. A total of 42,018 lobster was sampled from 16,144 trap hauls. The catch rate of marketable lobster, 0.671 lobster per trap, was only 6.3% lower than the 1992 index, 0.716. The proportion of females ovigerous, 14.3%, was higher than in the previous year (11.9%). The coast-wide fishing mortality estimate continued its increasing trend, reaching a new record high of 1.48. Exploitation rate, 0.69, remained the same as 1992 while mean carapace length of marketable lobster, 88.4 mm and mean size of egg-bearing females, 85.3 mm, declined slightly. The percentage of culls increased in every region sampled but one. Less than 1% of the lobster sampled from traps were dead.

The performance of the delta mean relative to the arithmetic mean, CTH'_3, was investigated for the years 1981-1993. The delta mean was slightly lower than CTH'_3 in all years but tracked it closely throughout the time series.

Sixth abdominal segment length (TL) and carapace length (CL) were measured on 1,858 lobster from Massachusetts coastal waters. A linear regression was calculated from the two variables and the resulting equation was used to predict the mean TL and its 99% confidence limits for lobster at the smallest legal CL (82.6 mm). The equation predicted a mean TL of 24.80 mm with 99% confidence limits of 22.80-26.80 mm.

A study was conducted to quantify the effects of the presence of ovigerous lobster in commercial lobster traps. This was accomplished by observing the condition and composition of the catch under three conditions: no eggers present; only small eggers present; or large eggers present. Traps containing large eggers had significantly greater numbers of dead lobster and significantly lower numbers of marketable lobster and sub-legal sized lobster.

INTRODUCTION

This is the Massachusetts Division of Marine Fisheries (DMF) thirteenth annual assessment of the status of the American lobster resource in Massachusetts coastal waters. Since the lobster resource supports the most economically important single-species fishery in Massachusetts coastal waters, a long-term coastwide lobster monitoring program yielding biological and catch per unit effort data was devised and initiated in Massachusetts in May, 1981. A sea sampling/survey design was chosen by which both catch per unit effort and biological data could be collected temporally and areally with sufficient precision for stock assessments. The objective was to assess variations in population parameters due to environmental factors, fishing pressure, and regulatory changes.

Data collected during the 1993 coastwide commercial lobster trap sampling program are summarized below. Parameter trends occurring during the 1981-1993 study period are presented.

STUDY AREA

The study area is primarily defined by the Massachusetts territorial sea, except where lobstering activities of cooperating commercial lobstermen exceeded territorial boundaries (Figure 1). Territorial waters total 5,322 sq km (2,055 sq n mi), of which an estimated 60% is considered major lobster habitat. Six sampling regions, Cape Ann, Beverly-Salem, Boston Harbor, Cape Cod Bay, outer Cape Cod, and Buzzards Bay, were chosen for coverage of the major lobstering regions of the state. For convenience, these regions are depicted in Figure 1 as generalized hatch-marked areas wherein lobster gear sampled may be discontinuously distributed.

SAMPLING PROCEDURE

Sampling of coastal waters was accomplished by monitoring catches during the normal lobstering operations of volunteer commercial lobstermen in each designated region. Multiple lobstering operations were observed to reduce bias from varying degrees of lobstering skill and to enhance areal coverage. Pot-sampling trips were day trips, conducted a minimum of once per month per region during the major lobstering season, May-November.

Utilizing portable cassette tape recorders, sea samplers recorded carapace length (to the nearest mm); sex; and condition, including the degree of shell hardness, culls and other shell damage, external gross pathology, mortality, and presence of extruded ova on females (ovigerous). Catch in number of lobster, number of trap hauls, set-over-days, trap and bait type were also recorded. Trap locations were recorded from LORAN and plotted on nautical charts. Depth information was then acquired from the charts as a coast-wide standard to avoid variability from tidal fluctuations.

ANALYTICAL PROCEDURES

Data were computer coded and keypunched with a microcomputer data entry program. The data base was subsequently transferred for analysis to the National Marine Fisheries Service's Digital Equipment Corporation VAX-11/780 computer system at the Woods Hole Oceanographic Institution. A computer auditing process was used to uncover keypunch and recording errors and statistical analyses were performed with SPSS (Nie 1983) statistical sub-programs.

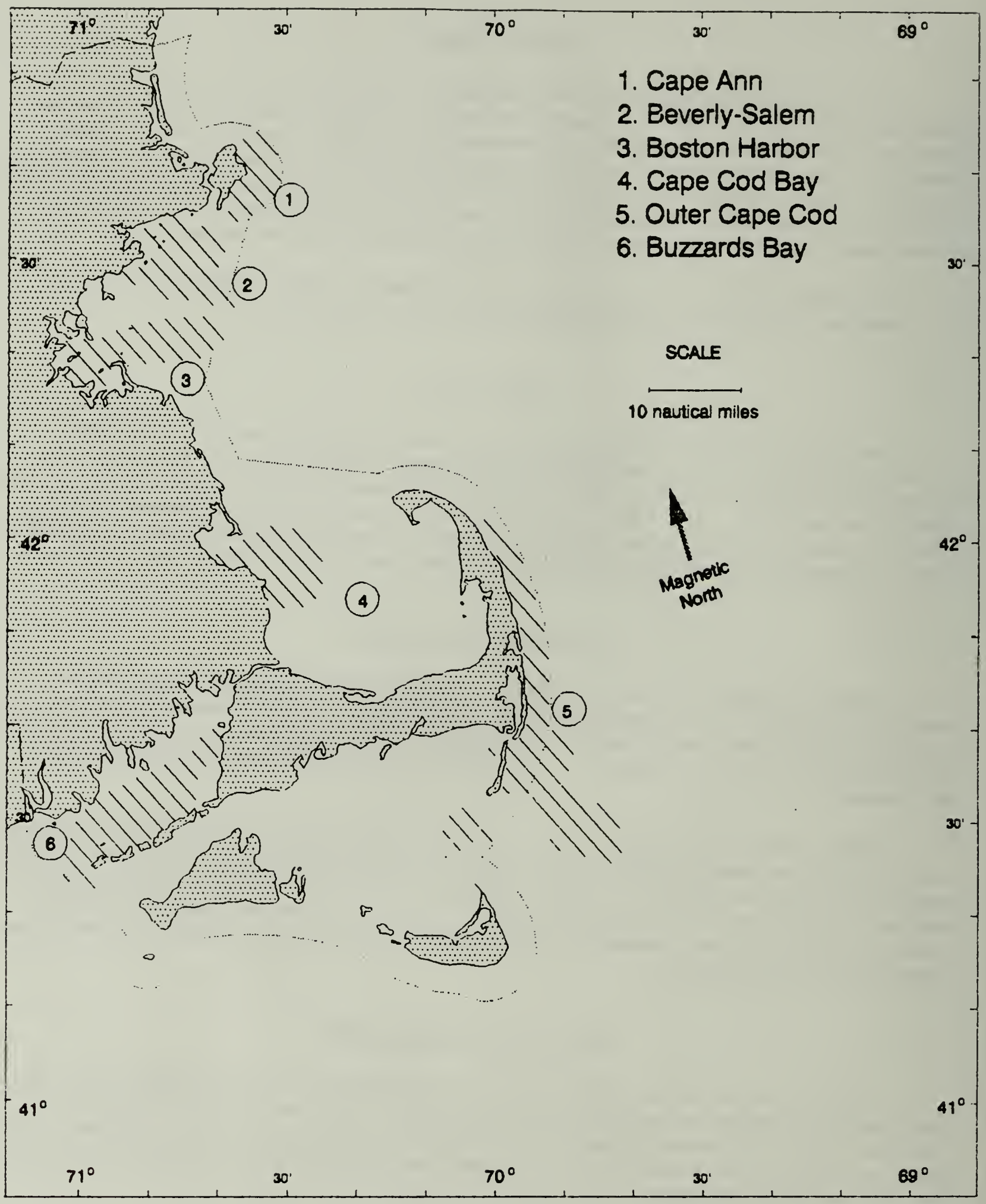

Figure 1. Map of Massachusetts coast with six sampling regions (hatch-marked) and territorial sea boundary (stippled).

Because parameter means exhibit significant regional and monthly variation, an areal and temporal data weighting scheme was incorporated into analytical software. As a result, each month's data contribute equally to regional parameter means which are weighted by area in square nautical miles to generate coastwide means.

Unless specified otherwise, the terms "legal" or "legal sized" lobster include all lobster in the carapace length category $\geq$ 82.6 mm. The marketable segment of this category, which excludes ovigerous females, is analyzed separately and referred to as "marketable lobster". The sublegal length category includes all lobster < 82.6 mm.

The catch rates of marketable lobster are expressed as CTH'_3. This is catch per trap haul standardized to 3 set-over-days (Estrella and McKiernan 1989).

Estimates of total instantaneous mortality (Z) and total annual mortality ($A=1-e^{-Z}$) were computed by two methods which produce extremes in the possible range of estimates. The method of Gulland (1969) requires computation of the regression line slope of natural log transformed numbers at estimated age (15% molt groups, 14% for Buzzards Bay, were derived from tagging data). Beverton and Holt's (1956) process employs von Bertalanffy Growth Equation parameters (from Fair 1977) and mean and minimum length of exploitable sizes.

Estimates of fishing mortality (F) were calculated with cohort analysis (Pope 1972). Rates of exploitation were calculated with the equation $u=FA/Z$, where F= fishing mortality, A= total annual mortality, and Z= total instantaneous mortality.

Lobster landings data were derived from lobstermen's catch reports which are compiled annually by the DMF Commercial Fisheries Statistics Project.

Since current management strategy stresses uniform coastwide regulations, all data are grouped for a coastwide analysis. However, the uniqueness of the Massachusetts coastline, its role as a temperature barrier which profoundly affects many marine species (Colton 1964), and the influence of offshore lobster stocks on the inshore resource mandate a regional data treatment as well.

RESULTS AND DISCUSSION

Commercial Lobster Sampling

During the period of May through November, 1993, eighty-five sampling trips were made aboard commercial lobster vessels in Massachusetts coastal waters. A total of 42,018 lobster was sampled from 16,144 trap hauls.

The 1993 coastwide mean catch per unit effort index (CTH'_3), 0.671 marketable lobster per trap, was 6.3% lower than the 1992 index, 0.716 (Appendix Table 1). Total Massachusetts commercial landings, 14,425,864 lbs, decreased by 3.6% from 1992. Landings from territorial waters, 9,124,412 lbs, decreased by 5.5%. Landings and catch rate trends are depicted in Figure 2. The catch rates of sublegal lobster increased significantly between 1992 and 1993 (Appendix Tables 2 and 3).

Of all females sampled during 1993, 14.3% were ovigerous compared to 11.9% in 1992 (Appendix Table 4). Trends in abundance of ovigerous females are depicted in Figure 3 (Appendix Tables 4-6).

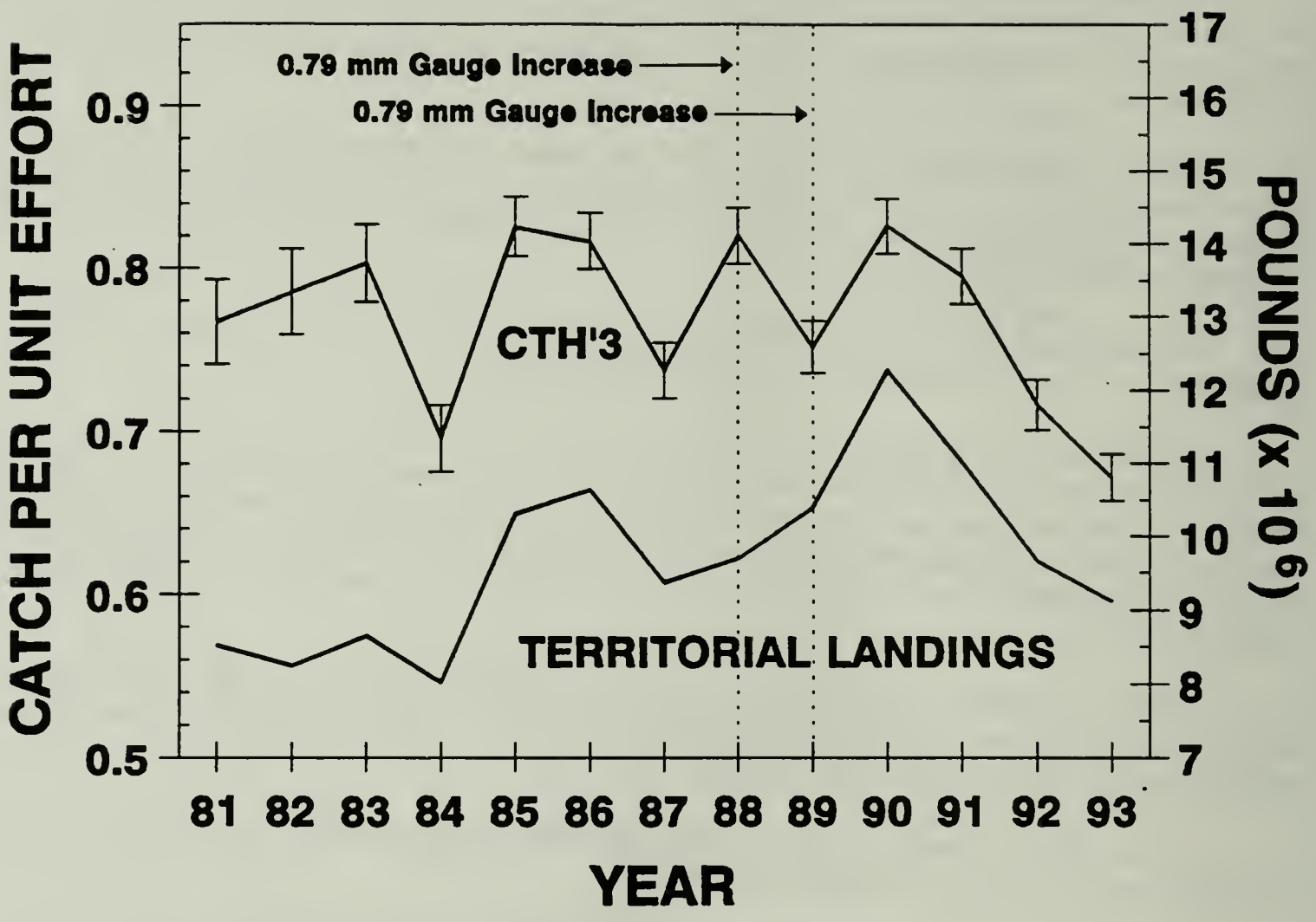

Figure 2. Catch per unit effort of marketable American lobster from commercial trap sampling and Massachusetts lobster landings from territorial waters, 1981-1993.

Approximately 93% of the legal catch in our inshore regions (Cape Ann south through Cape Cod Bay and Buzzards Bay) was comprised of new recruits (83 mm-94 mm CL), i.e., lobster which recruited to the legal size range during their most recent molt (Appendix Table 7). This index of the effect of fishing pressure on the size frequency was 94% in 1992. The index fluctuated from 57% to 60% between the two years for the primarily offshore migrant lobster sampled east of Cape Cod. Estimates of total mortality (Z) were similar to 1992 data. Indices for inshore Gulf of Maine regions (Z = 1.38-3.26, A = 75%-96%) and Buzzards Bay (Z = 3.03-3.11, A = 95%-96%) depict a heavily exploited resource while those for the outer Cape Cod region (Z = 0.78-0.87, A = 54%-58%) indicate that a lower level of fishing pressure was exerted on this lobster group (Appendix Tables 8a and 8b).

Estimates of instantaneous fishing mortality (F), the proportion of all deaths which are attributed to fishing, ranged from 0.65 off outer Cape Cod to 2.39 in Buzzards Bay (Appendix Table 9). Exploitation rates (u), i.e. the fraction of the population that is removed by fishing, were similar to 1992 data (Appendix Table 10).

The relationship between fishing mortality, rate of exploitation, and mean lobster size is depicted in Figure 4. Carapace length exhibited a downward trend as fishing mortality and exploitation rates increased through 1987. Thereafter carapace length increases of 0.7 mm occurred in 1988 (mean size = 88.2 mm) and 1989 (mean size = 88.9 mm, Appendix Table 11) which probably reflected the similar numerical change

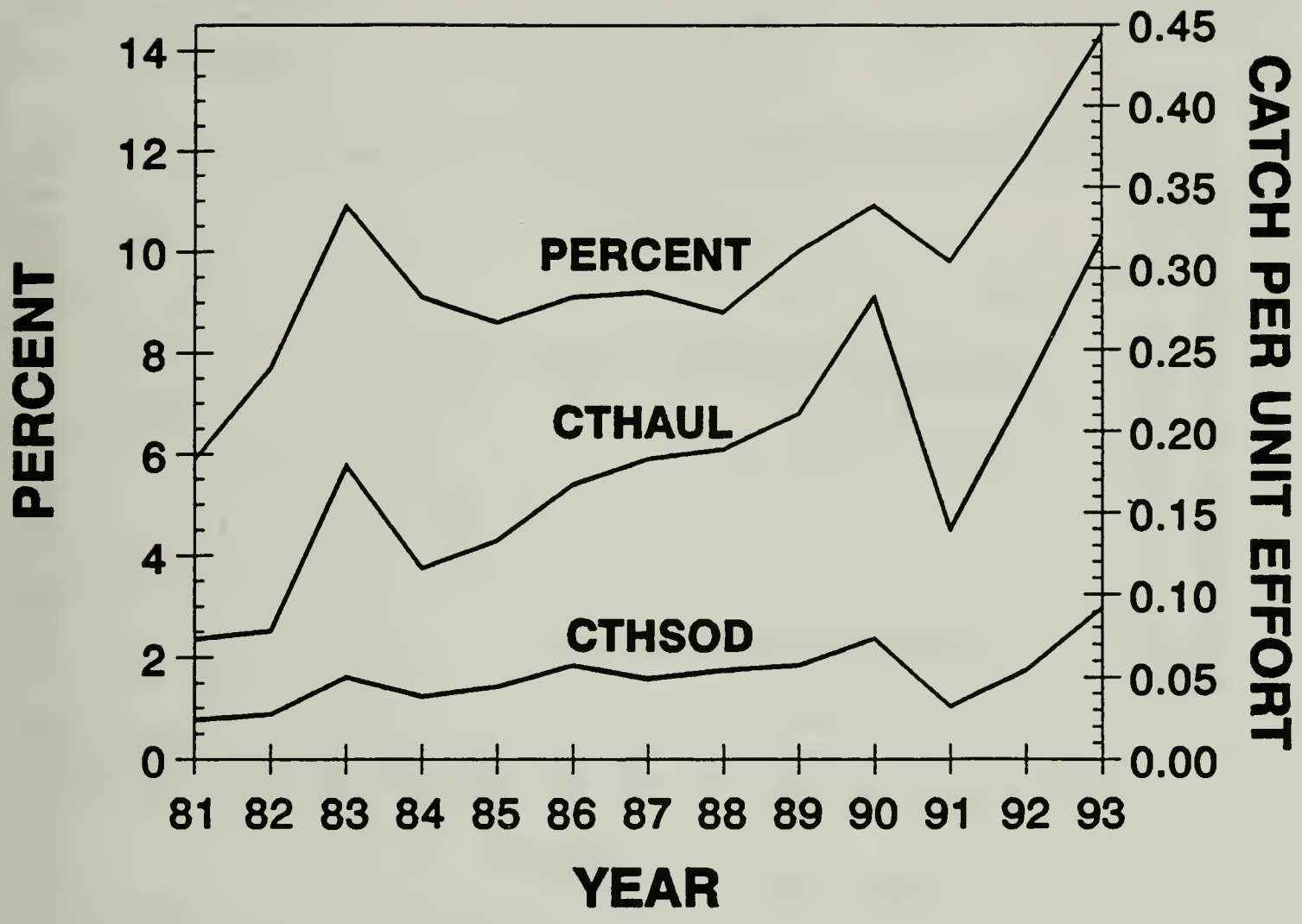

Figure 3. Relative abundance of ovigerous female American lobster in percent of total females and catch per unit effort, Massachusetts coastal waters, 1981-1993.

in the minimum legal size during those years. Fishing mortality rates have edged upward to a time-series high of 1.48 for all regions combined while exploitation rates appeared to stabilize.

Sublegal sized lobster averaged 76.9 mm carapace length during 1993 compared to 76.2 mm during 1992 (Appendix Table 12). The mean size of all ovigerous females decreased from 85.5 mm in 1992 to 85.3 mm in 1993.

The percentage of culls (lobster with one or both claws missing or regenerating) among all lobster sampled fluctuated upward from 18.5% in 1992 to 20.3% in 1993 (Appendix Table 14). The cull rates for legal and marketable size groups were similar while that for sublegal size groups increased from the previous year (Appendix Tables 15-17). The cull rate for Buzzards Bay increased substantially and nearly doubled for legal and marketable size groups.

The coast-wide incidence of lobster found dead in traps was 0.13%. This was similar to that of the previous year (Appendix Table 18) and is considered to be acceptably low.

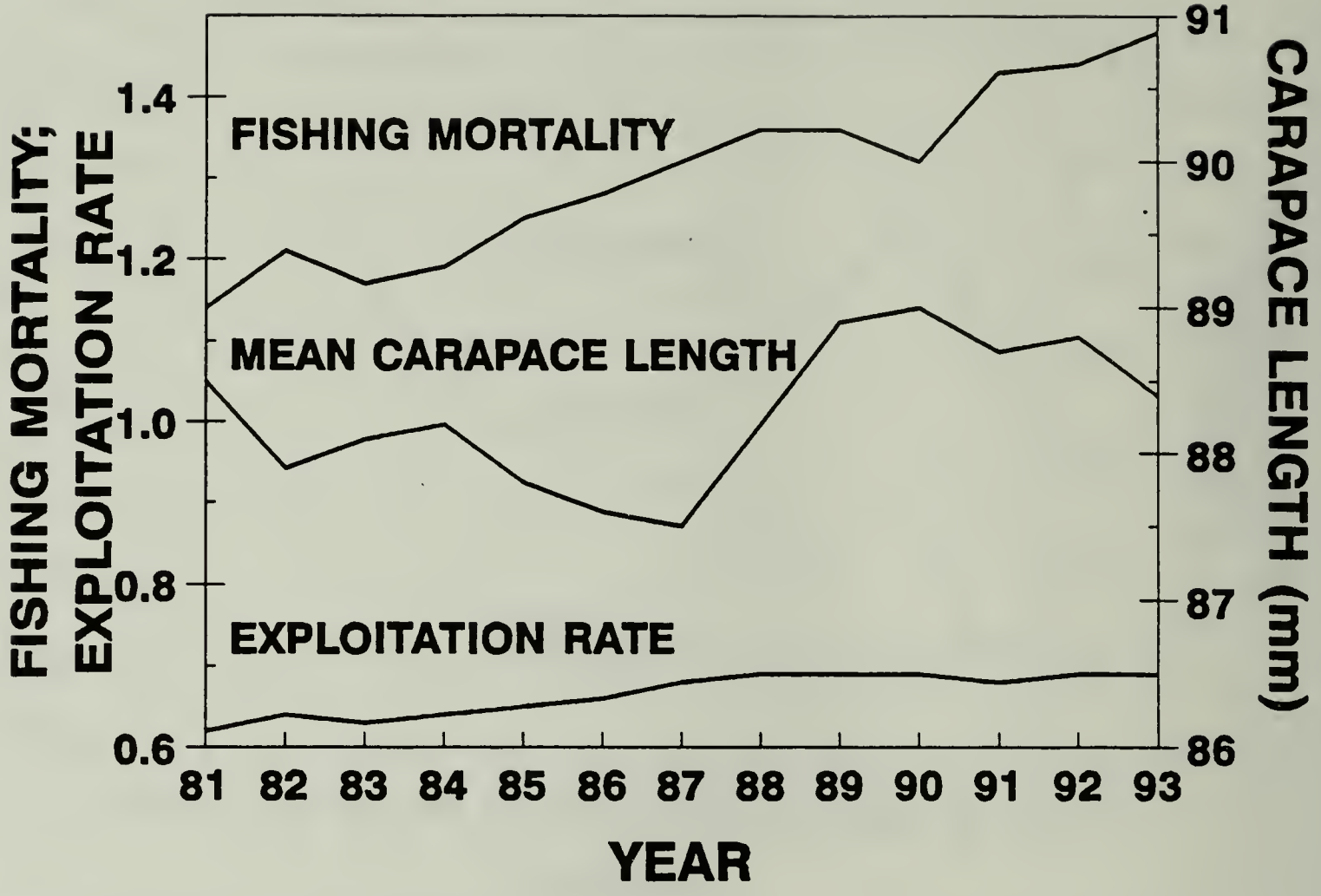

Figure 4. Relationship between exploitation rate, fishing mortality, and mean carapace length of marketable American lobster, Massachusetts coastal waters, 1981-1993.

INVESTIGATION OF THE APPLICATION OF THE DELTA MEAN TO SEA SAMPLING DATA

The performance of the delta mean relative to the arithmetic mean, CTH'_3, was investigated. The delta mean has been reported to be the best estimator of abundance of marine organisms when large numbers of zero observations are present in the data (Pennington, 1986; NUSCO, 1988). Such is the case for Massachusetts commercial lobster sea sampling data. The delta distribution is a generalized form of the lognormal model in which some of the values are zero and the non-zero values follow a lognormal distribution. The actual computation of the delta mean involves complex calculations using three parameters: the mean of the log-transformed, non-zero values; the variance of this mean; and the proportion of non-zero values. The formulas used can be found in NUSCO (1988) or Pennington (1986).

The results are presented in Figure 5. The delta mean was slightly lower than CTH'_3 in each year but tracked it closely throughout the time series. The confidence intervals around the delta and arithmetic means were approximately the same length in each year.

The delta mean provided estimates of abundance only slightly different from the arithmetic mean. Due to the complexity of the calculation of the delta mean, it is felt that little benefit would be gained by incorporating it into the analysis of sea sampling data at this time.

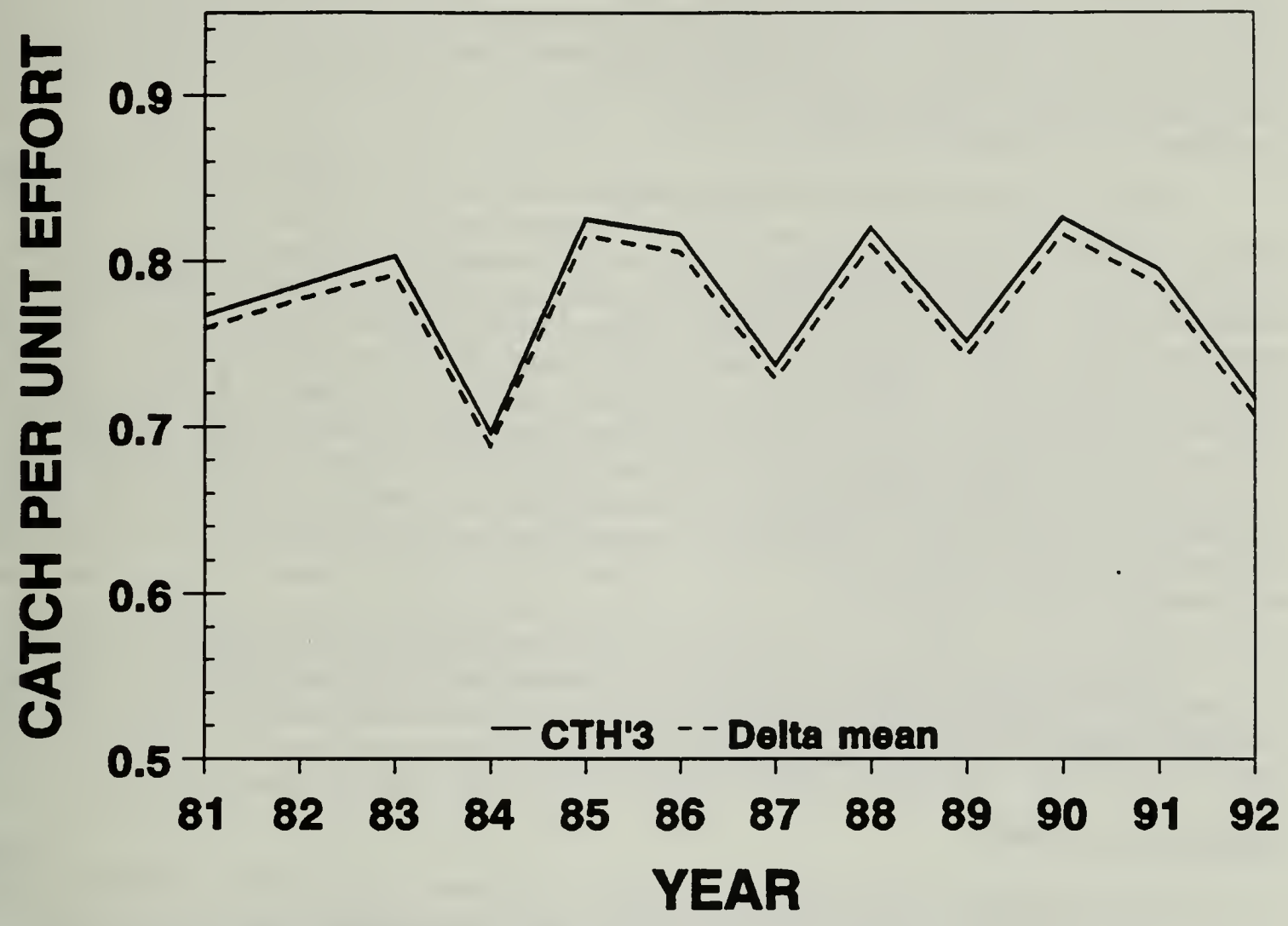

Figure 5. Comparison of annual values of CTH'3 and the delta mean, 1981-1992.

AGGRESSION IN OVIGEROUS AMERICAN LOBSTER: EVIDENCE FROM COMMERCIAL TRAP SAMPLING

The American lobster, *Homarus americanus*, is generally a solitary, aggressive animal in its natural habitat (Herrick, 1909; Cooper and Uzmann, 1980) and agonistic behavior is common when adults meet. These interactions serve to establish dominance and rarely result in physical damage although they frequently can lead to bouts of pushing and claw locking (Atema and Cobb, 1980). Most high level aggression is related to mature males attempting to establish a mating shelter and local dominance (Karnofsky et al., 1989). Factors influencing the outcome of agonistic encounters include body size, claw size, claw possession,

molt stage, and fighting experience (Scrivener, 1971; Atema and Cobb, 1980). Aggression in lobsters appears to be mediated by neurohormones, particularly serotonin (Kravitz, 1988).

Changes in levels of aggression have been reported in response to changes in population density, habitat quality, food availability, season, and life stage for a variety of species (Wilson, 1975). Increased aggression to protect eggs or young appears to be commonplace in nature. Lowe (1956) found that the crayfish, *Cambarellus shufeldtii*, exhibited increased aggression when bearing eggs, and ovigerous females were always dominant to males and non-ovigerous females. The ovigerous females descended in the social hierarchy after their eggs were released.

Little is known about the effects of egg-bearing on the level of aggression in the American lobster. Karnofsky and Price (1989), based on mesocosm observations, found that berried females were higher in the social hierarchy than expected, suggesting an increased level of aggression. Anecdotal evidence from lobstermen indicates ovigerous females (eggers) are extremely aggressive and must be handled carefully when removing them from traps. The confinement of eggers within the small area of lobster traps may increase their level of aggression. Karnofsky and Price (1989) found the frequency of high level aggressive acts in lobsters was much lower in their experimental mesocosm than in previous studies conducted in smaller tanks. The increased aggression of confined eggers may have deleterious effects on other lobsters within the trap. The inner parlors of lobster traps provide little opportunity for subordinate lobsters to withdraw from agonistic interactions, forcing prolonged encounters which may have physical or physiological consequences. The presence of eggers may also influence the composition or size of the catches in the traps by discouraging or encouraging entry into the trap.

The purpose of this study was to quantify the effects of the presence of ovigerous lobsters in commercial lobster traps by observing the condition and composition of the catch. We also tested for seasonal changes in these effects and for differences between females with recently extruded eggs (green eggers) and females with more mature eggs (brown eggers).

Materials and Methods

Data were collected during 1988-1992 as part of the Massachusetts Coastal Commercial Lobster Trap Sampling Program. Sea samplers collected biological and catch/effort data on board the vessels of cooperating commercial lobstermen in Massachusetts coastal waters during May-November of each year (see Cadrin and Estrella (1993) for complete description of sampling methodology). Each trap hauled represented a sampling unit. Data collected for each lobster included carapace length (mm), sex, shell hardness, mortality, presence of extruded ova, and fresh shell damage or missing chela(e).

To test for an effect of the presence of ovigerous females in traps, we examined five variables for each trap: percent of lobsters with fresh shell damage, other than missing chela(e) (PCTDAM); percent of lobsters missing one or both chela(e) (PCTCULL); percent of lobsters dead (PCTDEAD); number of lobsters less than 83 mm (82 mm for 1988 data) (#SUBLEGALS); and number of non-ovigerous lobsters greater than or equal to 83 mm (82 mm for 1988 data) (#MARKETS). PCTDAM, PCTCULL, and PCTDEAD were all considered potential indicators of recent intra-trap aggression. #SUBLEGALS and #MARKETS were indicators of the size composition and abundance of trap catches. For statistical analyses, we grouped the traps into three treatments according to whether there were no eggers present (Treatment 1), only eggers less than 96 mm (95 mm for 1988 data) present (Treatment 2), or only eggers greater than or equal to 96 mm (95 mm for 1988 data) present (Treatment 3). #MARKETS and #SUBLEGALS were standardized to three set-over-days (Estrella and McKiernan, 1989) to eliminate potential bias caused by different mean soak times among treatments.

The Kruskal-Wallis one-way ANOVA was used to test the null hypothesis that there was no difference in the ranks of treatments for the variables PCTDEAD, PCTCULL, PCTDAM, #SUBLEGALS, and #MARKETS. Mann-Whitney U-tests were used for multiple comparisons between treatments with alpha adjusted by the Bonferroni method (Snedecor and Cochran, 1989) to maintain the experimentwise alpha at 0.05 when the Kruskal-Wallis test was significant. The Kruskal-Wallis one-way ANOVA was also used to test for significant differences in monthly ranks in order to detect seasonal effects in PCTDAM, PCTCULL, and PCTDEAD. Spearman rank correlation coefficients were calculated between monthly mean bottom temperature and monthly mean values of PCTDAM, PCTCULL, and PCTDEAD to examine the relationship between temperature and these variables. Percent of lobsters with soft shells (SOFTSH) was also correlated with PCTDAM, PCTCULL, and PCTDEAD to examine that relationship. Mann-Whitney U-tests were used to test for significant differences in all five variables between green and brown eggers.

Data from three different coastal areas were analyzed separately because the biological characteristics of the lobster populations in these three areas are significantly different (Estrella and McKiernan, 1989). The three areas sampled were Gulf of Maine (GOM), Outer Cape Cod (OCC), and Buzzards Bay (BBAY) (Figure 1). Lobsters from GOM represent the inshore segment of the Gulf of Maine stock (National Marine Fisheries Service, 1993). These lobsters were collected from four sites: Cape Ann, Beverly-Salem Harbor, Boston Harbor, and Cape Cod Bay (Figure 1). They are relatively slow growing, reach 50% maturity (females) between 87-90 mm CL and have a median size (from commercial trap catches) of 80 mm CL (range 24-165 mm). OCC lobsters are from the offshore Southern New England-Georges Bank stock. They have a median size of 91 mm CL (range 36-191 mm), relatively low fishing pressure, and reach 50% maturity (females) at 97 mm CL. BBAY lobsters are part of the south of Cape Cod to Long Island inshore stock. They are relatively fast growing, reach 50% maturity (females) at 76 mm CL, have a median carapace length of 80 mm (range 28-145 mm), and are subject to extremely high fishing mortality (Estrella and McKiernan, 1989). Monthly bottom water temperature means, for use in the correlations, were calculated from data generated from continually recording temperature monitors located in BBAY and GOM. No water temperatures were available for OCC, so PCTDAM, PCTCULL, and PCTDEAD from OCC were correlated with water temperature means from GOM.

Results

A total of 81,388 traps were examined from the three regions. Of these, 63,964 contained lobsters and were used in the analyses: 50,264 from GOM; 5597 from OCC; and 8104 from BBAY.

There were no significant differences among the three treatments (1,2,3) for PCTDAM in any of the three geographic areas (Table 1). PCTCULL was not significantly different among treatments in GOM but traps with eggers had significantly higher culls than traps with no eggers in OCC and traps with no eggers or small eggers had significantly more culls than traps with large eggers in BBAY. PCTDEAD showed a significant difference in GOM and OCC; traps with large eggers (Treatment 3) always had a significantly higher percentage of dead lobsters than traps without eggers. #SUBLEGALS was significantly different in all three regions with Treatment 3 always having the lowest number of sublegal sized lobsters and Treatment 2 always having the highest number of sublegals. Results for #MARKETS indicate traps with no eggers (Treatment 1) had the highest number of marketable lobster in all three areas.

PCTCULL and PCTDEAD showed significant differences in monthly rank (Table 2 and Figure 6) in all regions indicating a seasonal component to these variables. PCTDAM showed monthly differences in GOM only.

PCTDAM and PCTDEAD showed no difference between large green and brown eggers (Table 3). PCTCULL was significantly higher in traps with green eggers than in traps with brown eggers in OCC only. The number of both sublegal and marketable lobsters was higher in traps with green eggers in

GOM and OCC while in BBAY the number of sublegal and marketable lobsters was higher in traps with brown eggers.

Bottom water temperature was positively correlated with PCTDEAD in BBAY and OCC (Table 4). In these two regions, water temperature and PCTDEAD both peaked in September (Figure 6A). There was no significant correlation between bottom water temperature and PCTDAM, and PCTCULL was positively correlated with bottom water temperature in GOM and OCC (Figure 6B). SOFTSH was not significantly correlated with PCTDAM or PCTDEAD in any of the three regions (Table 5), but PCTCULL was positively correlated to SOFTSH in OCC and BBAY.

Table 1. Results of Mann-Whitney U tests. Underlining indicates no significant difference ($p>0.017$, adjusted by Bonferroni procedure). Mean rank increases left to right within each test.

	N	Percent Culls (PCTCULL)	Percent Dead (PCTDEAD)	Percent Damaged (PCTDAM)	# of Sublegals (#SUBLEGALS)	# of Markets (#MARKETS)
Gulf of Maine	50526	1 3 2	1 2 3	3 2 1	3 1 2	2 3 1
Outer Cape	6215	1 2 3	1 2 3	3 1 2	3 1 2	3 2 1
Buzzards Bay	8474	3 2 1	3 2 1	3 2 1	3 1 2	2 3 1

1=no eggers present
2=small eggers only present (<96 mm, <95 mm for 1988)
3=large eggers only present (>96 mm, >95 mm for 1988)

Table 2. Results of Kruskal-Wallis one-way analysis of variance testing for significant differences between months, May through November (n.s. = $p>0.05$).

	N	Percent Culls (PCTCULL)	Percent Dead (PCTDEAD)	Percent Damaged (PCTDAM)
Gulf of Maine	50264	p=0.0000	p=0.0002	p=0.0000
Outer Cape	5597	p=0.0000	p=0.0021	n.s.
Buzzards Bay	8103	p=0.0000	p=0.0000	n.s.

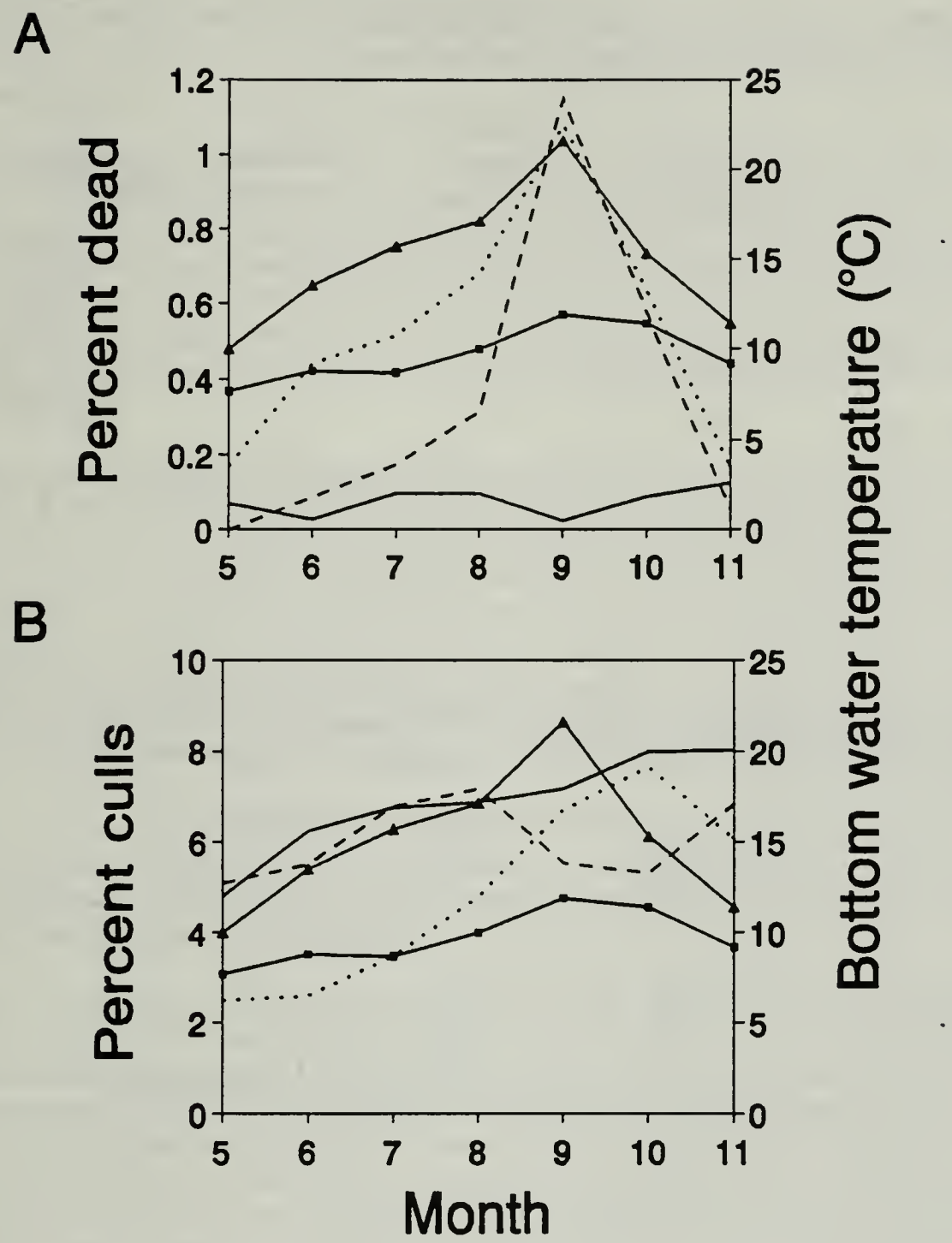

Figure 6. (A) Percent lobster dead in traps (PCTDEAD) and mean bottom water temperature plotted May-November. PCTDEAD is plotted for three regions separately: Gulf of Maine (solid line); Outer Cape Cod (dotted line); and Buzzards Bay (dashed line). Temperature is plotted for two areas: Gulf of Maine (solid line with square symbols); and Buzzards Bay (solid line with triangle symbols). (B) Percent lobsters with missing claws (PCTCULL) and mean bottom water temperature plotted May-November. PCTCULL is plotted for three regions separately: Gulf of Maine (solid line); Outer Cape Cod (dotted line); and Buzzards Bay (dashed line). Temperature is plotted for two areas: Gulf of Maine (solid line with square symbols); and Buzzards Bay (solid line with triangle symbols).

Table 3. Results of Mann-Whitney U tests. Testing for differences between large (>96 mm CL) green and brown eggers (n.s. = p>0.05). G=green eggers; B=brown eggers.

	N	Percent Culls (PCTCULL)	Percent Dead (PCTDEAD)	Percent Damaged (PCTDAM)	# of Sublegals (#SUBLEGALS)	# of Markets (#MARKETS)
Gulf of Maine	591	n.s.	n.s.	n.s.	p=0.0000 G>B	p=0.0301 G>B
Outer Cape	1577	p=0.0000 G>B	n.s.	n.s.	p=0.0052 G>B	p=0.0003 G>B
Buzzards Bay	128	n.s.	n.s.	n.s.	p=0.0042 B>G	p=0.0283 B>G

Table 4. Spearman rank correlation coefficients for correlations between bottom water temperature and the listed parameters using monthly means. (n.s. = correlation is not significant, p>.05)

	Percent Culls (PCTCULL)	Percent Dead (PCTDEAD)	Percent Damaged (PCTDAM)
Gulf of Maine	0.714	n.s.	n.s.
Outer Cape	0.893	0.750	n.s.
Buzzards Bay	n.s.	0.893	n.s.

Table 5. Spearman rank correlation coefficients for correlations between percent lobster with soft shells (SOFTSH) and the listed parameters using monthly means. (n.s. = correlation is not significant, p>.05)

	Percent Culls (PCTCULL)	Percent Dead (PCTDEAD)	Percent Damaged (PCTDAM)
Gulf of Maine	n.s.	n.s.	n.s.
Outer Cape	0.964	n.s.	n.s.
Buzzards Bay	0.964	n.s.	n.s.

Discussion

Four of the five variables examined showed significant differences between traps with no eggers, traps with small eggers, and traps with large eggers. However, these differences were not consistent among variables or among regions.

PCTDAM was the only variable that showed no significant differences among the three treatments in all regions (Table 1). This indicates that eggers in traps did not inflict body damage on conspecifics at a rate higher than that which normally occurred in trapped lobsters. However, it was noted during field sampling that when traps were hauled, most of the lobsters in a trap fell into a pile at one end of the inner parlor. Lobsters within this pile instinctively clamped their claws on whatever was in contact with them, frequently conspecific's body parts. Any resulting damage could not be distinguished from damage occurring before the trap was hauled. This damage may have masked the effect of damage caused by aggressive eggers prior to the trap being hauled.

PCTCULL can be considered a specialized form of shell damage, and was by far the most frequently seen damage. The causes of claw loss include conspecific fights as well as attacks by predators, molting difficulties, and handling by fishermen (Atema and Cobb, 1980). In OCC, the presence of eggers increased the cull rate. Traps in OCC are hauled less frequently than traps in the other regions (unpublished data) resulting in longer soak times and consequently, potentially more time for entrapped lobsters to interact. The significant difference in cull rate for this region may be a function of these elongated soak times. Conversely, in BBAY, the cull rate was higher in traps with no eggers or small eggers. The inconsistency of the results among regions leads us to question the validity of PCTCULL as a measure of intra-trap aggression. PCTCULL may not be a reliable measure because of the alternative causes of culls.

PCTCULL was found to be positively correlated with SOFTSH in two of three regions (Table 5), indicating that lobsters with soft shells were more likely to lose a claw than hard shelled lobsters. The significant monthly differences in PCTCULL (Table 2) may be the result of seasonality in several factors including molting, fishing effort, and lobster activity.

PCTDEAD was found to be higher in traps containing large eggers than in traps without eggers in two of three regions (Table 1). This variable provides the best evidence for intra-trap aggression by ovigerous lobsters. In some cases, the cause of death was obvious such as a massive wound. In many cases there was no external damage present and the cause of death was not evident. We speculate that physiological stress resulting from entrapment and exacerbated by the presence of an aggressive female may have contributed to death in these circumstances. The positive correlation between bottom water temperature and PCTDEAD is likely the result of additional physiological stress caused by high water temperature during the late summer. The highest correlation occurred with data from Buzzards Bay where the bottom water temperature was higher than in the Gulf of Maine. Additionally, lobsters become more aggressive with increasing temperatures (Hoffman et al., 1975) and this may intensify the effect of having an egger present.

Traps with small eggers consistently had the highest number of sublegal sized lobsters, while traps with large eggers consistently had the lowest number (Table 1). This suggests that larger lobsters either discouraged the entry of sublegals into the traps or caused the sublegals to exit once they had entered the trap. Sublegals could exit traps readily by utilizing the escape vent which is incorporated into all commercial traps in Massachusetts waters. Richards et al. (1983) found the presence of conspecifics in a trap significantly reduced the number of lobsters subsequently entering that trap. They also found that catches of Jonah crab, *Cancer borealis*, were similarly reduced, and behavioral observations showed that lobsters deterred the entry of rock crabs into the inner parlor by agonistic behavior. In the present study, the finding of significantly fewer sublegal lobsters in traps containing large eggers may be the result of this agonistic

behavior. Olfactory cues may also be involved in deterring sublegals from entering traps (Karavanich and Atema, 1991). Conversely, sublegals appeared to be attracted to traps containing small eggers or vice versa. In two of three regions, traps with small eggers had higher mean catches of sublegals than traps with no eggers. Attraction in lobsters has only been documented in courting pairs. It has widely been accepted that female lobsters produce pheromones at or around the time of ecdysis that function as attractants to males. Recent evidence, however, suggests that male pheromones serving to attract females are more likely (Cowan, 1991). There is no experimental evidence that attractants are released by ovigerous females, but that possibility can not be ruled out as an explanation for the increased catch of sublegal sized lobsters although it is difficult to explain why this would only be found in small eggers and not large eggers.

However, an alternative explanation exists for the differences in catches of sublegals between treatments which is based on their geographic distributions rather than social interactions in or around traps. Sublegals may simply not occur in abundance in areas where large eggers congregate, but may co-occur with small eggers and so the differences in catch rates among groups may reflect differential habitat use by large eggers, small eggers, and sublegals. This would indicate segregation primarily by size. The data were analyzed regionally to minimize such an effect, and therefore differences in habitat use would need to be on a relatively small scale, within a single region. Little information exists on the fine-scale distribution of lobsters at different sizes and reproductive conditions.

In OCC and GOM, the results for #MARKETS followed the pattern that would be expected if eggers were actively excluding larger, marketable lobsters either by agonistic behavior or by olfactory cues. However, the pattern could also be explained by fine scale differences in distribution, for instance, if eggers were geographically segregated from males and non-ovigerous females. This would indicate that lobsters were segregating by reproductive condition rather than size. This is supported by work by Campbell and Pezzack (1986) and Campbell (1990) who found concentrations of ovigerous females in the Bay of Fundy.

Observations by lobstermen and sea samplers indicated that brown eggers were more aggressive than green eggers. These observations were not supported by the comparisons of PCTDEAD, PCTDAM, and PCTCULL between green and brown eggers (Table 3). However, fewer #SUBLEGALS and #MARKETS occurred with brown eggers in two of three regions, suggesting that brown eggers do have a deleterious effect on catches.

In summary, significant but inconsistent trends were found in several of the variables examined. The effect of ovigerous lobsters in traps was strongest in the Outer Cape Cod region (significant differences in four of five variables) where large eggers are prevalent and weakest in Buzzards Bay (significant differences in two of five variables) where few large eggers occur. PCTDEAD, #SUBLEGALS, and #MARKETS provided the best evidence for intra-trap aggression by eggers although the results for #SUBLEGALS and #MARKETS may be confounded by distributional differences by size, sex or reproductive condition. The results become difficult to interpret if we examine the data beyond a regional analysis. The unique biological characteristics of the populations examined may be responsible for that effect. Additional work on aggression in ovigerous American lobster should concentrate on finer scale sampling to eliminate the possible problem of differential habitat use, and laboratory or field experimentation which standardize extraneous variables, especially trap type and trap size, which may have confounded these analyses.

ANALYSIS OF SIXTH TAIL SEGMENT-CARAPACE LENGTH RELATIONSHIP

The use of sixth abdominal segment length (TL) as a standard for minimum legal size was first proposed by Halgren (1974) for the New Jersey Bureau of Fisheries. To develop the standard, he measured carapace length (CL), TL, and a variety of other tail measurements from lobster harvested near Hudson Canyon. He found that TL had the most linear and least variable relationship to CL by simple least-squares regression and suggested regulating a minimum legal TL based on the upper 99% confidence limit for mean TL at minimum legal CL. Briggs (1976) adopted Halgren's method to develop a minimum legal TL for the New York Division of Marine Resources.

TL and CL were measured (to 0.1 mm) in 1,858 lobster during commercial lobster trap sampling in 1991-1994. Lobster were sampled in all regions except region 2, Beverly-Salem Harbor. A model I regression was calculated from the two variables. Although both variables were measured with error, a model II regression was not used because a model I regression is more appropriate when the resulting equation is to be used for predictive purposes (Sokal and Rohlf, 1981). The regression was used to calculate the mean TL and its 99% confidence limits for lobster at the smallest legal CL (82.55 mm, 3.25").

Because a single minimum legal TL is desirable for all lobster landed or marketed in Massachusetts, all data were pooled for the regression. The regression equation was (measurements in mm):

$$TL = 1.27202 + 0.28498(CL) \;;\; r^2 = 0.89$$

This equation predicts a mean TL at 82.55 mm (3.25") CL of 24.80 mm (0.976"). The 99% confidence limits around the TL are 22.80 mm (0.898") - 26.80 mm (1.055"). The upper limit is equal to approximately 1 1/16". We propose this as the minimum legal TL to be used if such a need arises.

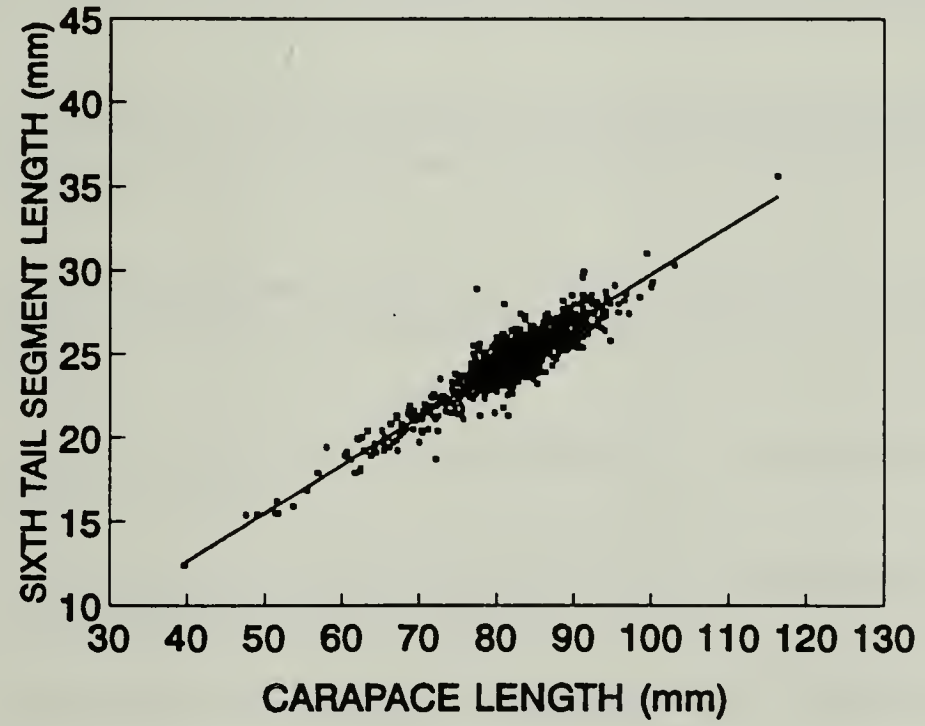

Figure 7. Relationship between sixth tail segment length and carapace length in American lobster.

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APPENDIX

Table 1. CTH'3, by state and region, for all marketable lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	0.767	0.785	0.803	0.696	0.825	0.816	0.737	0.828	0.751	0.826	0.795	0.719	0.671
Cape Ann	0.732	0.808	0.624	0.663	0.634	0.699	0.669	0.496	0.721	0.904	0.868	0.724	0.770
Beverly-Salem	0.934	0.898	0.881	0.835	0.663	0.496	0.611	0.661	0.639	0.827	0.586	0.390	0.509
Boston Harbor	---	---	---	1.108	1.254	1.096	1.058	1.057	1.123	1.224	1.160	0.734	0.750
Cape Cod Bay	0.710	0.776	0.680	0.479	0.716	0.822	0.533	0.752	0.539	0.630	0.693	0.567	0.494
Outer Cape Cod	0.808	0.824	0.765	0.598	0.856	0.811	0.937	0.861	0.923	1.219	1.148	1.339	1.021
Buzzards Bay	0.611	0.571	1.110	0.870	0.953	0.907	0.952	1.064	0.934	0.598	0.575	0.817	0.834

Table 2. CTHSOD, by state and region, for all sub-legal American lobster, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	0.580	0.672	0.718	0.521	0.647	0.700	0.578	0.509	0.695	0.716	0.665	0.465	0.542
Cape Ann	0.067	0.109	0.586	0.450	0.395	0.474	0.417	0.388	0.670	0.589	0.728	0.726	0.447
Beverly-Salem	0.708	0.711	1.263	0.948	0.833	0.801	0.863	0.353	0.780	0.408	0.324	0.411	0.406
Boston Harbor	---	---	---	0.901	1.162	1.138	1.156	0.639	0.966	1.103	0.924	0.839	0.800
Cape Cod Bay	0.710	1.013	0.639	0.322	0.594	0.551	0.371	0.438	0.595	0.727	0.716	0.298	0.436
Outer Cape Cod	0.037	0.024	0.038	0.033	0.035	0.027	0.088	0.064	0.066	0.078	0.077	0.088	0.075
Buzzards Bay	0.787	0.620	0.638	0.785	0.848	1.312	0.871	1.153	1.188	1.236	1.072	0.784	1.156

Table 3. CTHAUL, by state and region, for all sub-legal American lobster, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	1.473	1.401	1.624	1.389	1.705	1.899	1.873	1.736	2.297	2.216	1.996	1.460	1.720
Cape Ann	0.256	0.199	1.044	0.909	1.031	1.126	1.143	1.062	1.765	1.782	1.783	1.661	1.562
Beverly-Salem	1.855	1.713	2.526	2.504	2.567	2.435	3.482	1.862	3.477	1.867	1.563	1.502	1.540
Boston Harbor	---	---	---	2.773	3.038	3.314	3.334	1.959	3.104	3.382	2.451	2.069	2.284
Cape Cod Bay	1.544	1.680	1.345	0.825	1.337	1.512	1.031	1.442	1.742	1.921	2.086	1.065	1.334
Outer Cape Cod	0.233	0.145	0.210	0.189	0.160	0.161	0.324	0.353	0.306	0.453	0.452	0.490	0.474
Buzzards Bay	2.381	1.916	2.316	1.965	2.452	3.118	3.090	3.722	3.984	3.994	3.181	2.602	3.501

Table 4. Percent of females ovigerous, by state and region, for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	5.9	7.7	10.9	9.1	8.6	9.1	9.2	8.8	10.0	10.9	9.8	11.9	14.3
Cape Ann	1.7	3.1	4.4	3.2	4.6	5.0	4.5	3.5	6.3	6.9	4.3	6.7	9.3
Beverly-Salem	1.7	2.8	1.2	0.4	1.9	1.1	1.8	1.5	1.6	1.8	3.2	3.9	5.4
Boston Harbor	---	---	---	1.4	1.2	2.0	1.7	2.0	2.1	2.7	2.8	3.0	4.4
Cape Cod Bay	3.9	3.1	3.7	3.1	3.2	2.1	3.9	2.9	3.0	3.3	5.4	6.8	6.8
Outer Cape Cod	11.1	23.0	30.3	26.8	22.3	28.9	16.9	21.4	27.4	24.5	18.3	27.7	26.8
Buzzards Bay	16.0	16.9	32.5	26.6	25.0	25.3	31.0	27.8	29.2	35.0	28.2	28.8	40.9

Table 5. CTHSOD, by state and region, for all ovigerous female American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	0.024	0.027	0.050	0.038	0.044	0.057	0.049	0.054	0.057	0.073	0.032	0.054	0.092
Cape Ann	0.002	0.011	0.024	0.015	0.016	0.017	0.016	0.010	0.037	0.035	0.024	0.050	0.038
Beverly-Salem	0.011	0.009	0.008	0.003	0.011	0.004	0.010	0.004	0.009	0.005	0.008	0.014	0.020
Boston Harbor	---	---	---	0.009	0.007	0.015	0.012	0.012	0.010	0.028	0.017	0.017	0.026
Cape Cod Bay	0.020	0.025	0.016	0.009	0.015	0.010	0.012	0.009	0.014	0.017	0.028	0.016	0.023
Outer Cape Cod	0.012	0.028	0.040	0.030	0.038	0.032	0.034	0.030	0.043	0.055	0.038	0.076	0.053
Buzzards Bay	0.079	0.053	0.230	0.183	0.193	0.297	0.234	0.289	0.270	0.349	0.073	0.197	0.446

Table 6. CTHAUL, by state and region, for all ovigerous female American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	0.073	0.078	0.179	0.116	0.138	0.167	0.183	0.189	0.241	0.282	0.148	0.227	0.319
Cape Ann	0.010	0.016	0.038	0.027	0.039	0.047	0.048	0.031	0.096	0.109	0.056	0.088	0.135
Beverly-Salem	0.025	0.033	0.016	0.006	0.033	0.018	0.036	0.021	0.039	0.023	0.049	0.047	0.067
Boston Harbor	---	---	---	0.030	0.025	0.050	0.037	0.038	0.043	0.075	0.064	0.046	0.081
Cape Cod Bay	0.048	0.048	0.040	0.024	0.040	0.031	0.038	0.034	0.039	0.055	0.091	0.056	0.078
Outer Cape Cod	0.081	0.178	0.242	0.170	0.176	0.225	0.157	0.198	0.258	0.342	0.251	0.453	0.317
Buzzards Bay	0.243	0.139	0.828	0.515	0.555	0.748	0.889	0.929	0.953	1.291	0.359	0.847	1.438

Table 7. Estimated fishing pressure index, by state and region, commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	86	87	86	86	88	88	89	90	88	87	89	89	90
Cape Ann	91	92	87	89	87	87	88	90	84	81	90	87	83
Beverly-Salem	89	92	94	88	96	96	97	98	96	95	97	98	96
Boston Harbor	---	---	---	93	94	96	96	96	96	95	96	95	96
Cape Cod Bay	90	93	92	94	93	94	92	94	94	93	91	92	94
Outer Cape Cod	46	43	42	38	48	46	54	57	47	50	54	57	60
Buzzards Bay	98	96	96	94	96	97	97	97	95	94	95	97	97

Table 8A. Total Instantaneous (Z)* and total annual (A)** mortality estimates (Gulland, 1969) of American lobster by state and region, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	1.58 *	1.72	1.66	1.66	1.76	1.80	1.90	1.86	1.80	1.76	1.90	1.92	1.86
	79% **	82%	81%	81%	83%	84%	85%	84%	83%	83%	85%	85%	84%
Cape Ann	1.65	2.18	1.72	1.92	1.94	2.03	1.85	1.75	1.55	1.39	1.97	1.87	1.51
	81%	89%	82%	85%	86%	87%	84%	83%	79%	75%	86%	85%	78%
Beverly-Salem	1.97	2.15	2.41	2.71	3.64	3.60	3.49	3.31	3.59	2.81	3.49	3.12	2.62
	86%	88%	91%	93%	97%	97%	97%	96%	97%	94%	97%	96%	93%
Boston Harbor	---	---	---	2.52	3.59	2.60	2.77	2.86	2.96	3.00	3.40	3.54	3.26
	---	---	---	92%	97%	93%	94%	94%	95%	95%	97%	97%	96%
Cape Cod Bay	2.53	2.69	2.42	2.52	2.31	2.83	2.26	2.74	2.43	2.46	2.33	2.58	2.60
	92%	93%	91%	92%	90%	94%	90%	94%	91%	91%	90%	92%	93%
Outer Cape Cod	0.43	0.46	0.42	0.33	0.52	0.51	0.80	0.71	0.62	0.63	0.77	0.78	0.87
	35%	37%	34%	28%	41%	40%	55%	51%	46%	47%	54%	54%	58%
Buzzards Bay	3.02	3.00	8.64	3.14	3.55	3.71	3.48	3.18	3.13	2.60	3.50	3.81	3.03
	95%	95%	99%	96%	97%	98%	97%	96%	96%	93%	97%	98%	95%

Table 8B. Total Instantaneous (Z)* and total annual (A)** mortallty estimates (Beverton and Holt, 1956) of American lobster by state and region, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	1.35 *	1.45	1.39	1.41	1.47	1.49	1.54	1.56	1.53	1.50	1.73	1.70	1.79
	74% **	77%	75%	76%	77%	78%	79%	79%	78%	78%	82%	82%	83%
Cape Ann	1.32	1.39	1.35	1.52	1.33	1.32	1.39	1.51	1.27	1.66	1.77	1.57	1.38
	73%	75%	74%	78%	74%	73%	75%	78%	72%	81%	83%	79%	75%
Beverly-Salem	1.59	1.70	1.85	1.78	1.96	1.99	2.16	1.98	2.01	1.83	2.29	2.50	2.23
	80%	82%	84%	83%	86%	86%	88%	86%	87%	84%	90%	92%	89%
Boston Harbor	---	---	---	1.82	1.75	1.92	1.88	1.84	1.94	1.87	2.19	2.14	2.33
	---	---	---	84%	83%	85%	85%	84%	86%	85%	89%	88%	90%
Cape Cod Bay	1.64	1.92	1.72	2.07	1.88	1.92	1.78	1.87	1.97	1.95	1.96	2.01	2.14
	81%	85%	82%	87%	85%	85%	83%	85%	86%	86%	86%	87%	88%
Outer Cape Cod	0.54	0.55	0.53	0.52	0.57	0.55	0.66	0.66	0.62	0.63	0.71	0.72	0.78
	42%	42%	41%	41%	43%	42%	48%	48%	46%	47%	51%	51%	54%
Buzzards Bay	2.97	2.53	2.26	2.21	2.36	2.41	2.36	2.35	2.14	2.27	3.08	2.70	3.11
	95%	92%	90%	89%	91%	91%	91%	94%	88%	90%	95%	93%	96%

Table 9. Instantaneous fishing mortallty estimates (F), by state and region, commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	1.14	1.21	1.17	1.19	1.25	1.28	1.32	1.36	1.36	1.32	1.43	1.44	1.48
Cape Ann	1.33	1.47	1.11	1.33	1.28	1.22	1.30	1.37	1.12	1.04	1.50	1.32	1.14
Beverly-Salem	1.42	1.47	1.64	1.68	1.81	1.93	1.89	2.02	1.95	1.86	2.08	2.16	1.96
Boston Harbor	---	---	---	1.77	1.70	1.80	1.87	1.83	1.94	1.86	2.01	1.97	1.97
Cape Cod Bay	1.53	1.60	1.58	1.73	1.59	1.70	1.56	1.70	1.82	1.72	1.66	1.71	1.85
Outer Cape Cod	0.47	0.48	0.45	0.42	0.47	0.47	0.57	0.53	0.54	0.51	0.59	0.61	0.65
Buzzards Bay	2.32	2.13	1.94	1.80	2.04	2.11	2.08	2.06	1.95	1.97	2.34	2.26	2.39

Table 10. Estimated exploitation rate (u), by state and region, commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	0.62	0.64	0.63	0.64	0.65	0.66	0.68	0.69	0.69	0.69	0.68	0.69	0.65
Cape Ann	0.74	0.80	0.61	0.68	0.71	0.67	0.70	0.71	0.63	0.51	0.70	0.67	0.62
Beverly-Salem	0.71	0.71	0.75	0.79	0.79	0.83	0.77	0.88	0.76	0.85	0.82	0.79	0.78
Boston Harbor	---	---	---	0.82	0.81	0.80	0.84	0.84	0.86	0.85	0.82	0.81	0.76
Cape Cod Bay	0.75	0.71	0.75	0.73	0.72	0.75	0.73	0.77	0.79	0.76	0.73	0.74	0.76
Outer Cape Cod	0.37	0.37	0.35	0.33	0.36	0.36	0.41	0.38	0.40	0.38	0.42	0.44	0.45
Buzzards Bay	0.74	0.78	0.77	0.72	0.79	0.80	0.80	0.82	0.80	0.78	0.72	0.78	0.74

Table 11. Mean carapace length (mm), by state and region, for all marketable American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	88.5	87.9	88.1	88.2	87.3	87.6	87.5	88.2	88.9	89.0	88.7	88.9	88.4
Cape Ann	88.6	88.3	88.3	87.9	88.4	88.3	88.0	88.3	89.3	90.3	88.4	88.8	89.6
Beverly-Salem	87.6	87.0	86.6	86.9	86.2	86.2	85.8	87.1	87.7	88.3	87.5	87.2	87.5
Boston Harbor	---	---	---	86.8	86.9	86.4	86.6	87.5	88.0	88.1	87.8	87.9	87.5
Cape Cod Bay	87.2	86.4	86.9	86.1	86.4	86.3	86.7	87.3	87.7	87.7	88.1	88.2	87.7
Outer Cape Cod	98.2	97.5	97.4	99.7	97.0	96.3	94.6	95.2	96.5	96.1	95.3	95.2	93.8
Buzzards Bay	84.7	85.2	85.7	85.8	85.2	85.3	85.3	86.1	87.4	87.0	86.4	86.9	86.5

Table 12. Mean carapace length (mm), by state and region for all sub-legal American lobster, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	75.8	76.3	76.2	76.1	76.3	76.1	76.1	76.3	77.5	77.6	76.7	76.2	76.9
Cape Ann	78.0	77.7	77.5	77.3	77.6	77.1	75.9	77.0	78.3	78.8	78.7	77.9	78.3
Beverly-Salem	74.3	76.5	74.9	76.1	75.9	74.7	74.7	74.5	76.4	76.1	73.4	73.5	75.1
Boston Harbor	---	---	---	77.1	76.9	76.9	76.5	75.6	76.8	77.4	75.4	74.6	75.3
Cape Cod Bay	76.6	76.4	76.7	75.6	76.1	76.2	75.6	76.9	77.9	77.8	77.4	76.8	76.7
Outer Cape Cod	75.9	76.2	77.1	75.1	76.6	75.9	77.0	77.1	76.8	78.8	78.8	79.0	79.4
Buzzards Bay	75.8	75.5	76.8	76.4	76.1	76.0	76.6	76.3	77.7	77.4	76.6	77.1	78.3

Table 13. Mean carapace length (mm) of all ovigerous female American lobster, by state and region, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	88.5	87.6	88.6	87.4	87.9	88.1	87.1	87.4	88.5	88.0	86.0	85.5	85.3
Cape Ann	109.0	100.3	94.3	90.5	93.8	95.0	91.6	94.0	100.4	95.1	91.7	91.9	91.0
Beverly-Salem	80.5	84.5	85.8	83.5	85.9	83.5	81.8	83.0	85.2	85.5	83.8	81.6	82.6
Boston Harbor	---	---	---	82.1	84.0	81.3	82.3	83.7	83.0	83.8	82.0	82.0	80.8
Cape Cod Bay	86.4	83.8	85.5	84.4	85.2	86.8	87.0	84.7	86.1	85.0	83.9	84.1	83.0
Outer Cape Cod	109.8	106.1	108.0	107.1	106.9	107.3	102.5	105.2	105.4	104.6	101.9	99.2	100.7
Buzzards Bay	78.1	79.6	81.6	83.0	80.1	79.4	80.2	80.6	81.3	80.8	79.8	79.9	81.0

Table 14. Cull rate (percent), by state and region, for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	10.0	10.8	10.7	14.8	18.1	20.9	17.0	18.2	19.2	18.6	18.1	18.5	20.3
Cape Ann	10.0	9.8	10.5	11.5	23.9	25.3	20.2	21.2	16.7	16.7	19.7	18.2	19.2
Beverly-Salem	8.3	8.6	10.2	20.9	23.0	30.0	24.1	26.3	28.6	27.3	28.9	22.7	28.3
Boston Harbor	---	---	---	13.3	19.3	19.1	16.9	16.3	13.8	14.7	13.5	17.2	23.4
Cape Cod Bay	11.1	10.7	10.9	15.6	18.3	21.6	16.2	17.4	22.8	20.5	18.9	18.3	18.1
Outer Cape Cod	5.7	11.3	8.9	13.0	13.4	16.1	12.6	15.0	14.0	15.5	13.2	15.7	17.3
Buzzards Bay	13.5	14.7	12.4	12.4	13.4	14.6	15.1	15.6	12.6	13.6	13.9	19.3	20.5

Table 15. Cull rate (percent), by state and region, for all legal-sized American lobster, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	8.1	9.7	9.2	12.7	14.8	17.0	14.7	15.7	14.9	15.4	15.6	17.1	17.4
Cape Ann	10.7	9.6	7.5	10.4	19.4	20.3	18.0	19.3	13.9	13.7	16.8	18.3	16.3
Beverly-Salem	4.3	7.7	7.4	15.5	19.3	22.1	17.1	21.4	18.7	25.6	22.8	19.9	24.6
Boston Harbor	---	---	---	10.1	16.2	15.8	12.9	13.1	9.9	9.9	12.3	14.0	17.5
Cape Cod Bay	9.3	9.3	10.0	13.2	14.5	18.1	15.0	15.6	12.0	16.3	17.8	16.8	16.3
Outer Cape Cod	5.3	10.3	8.1	13.3	12.5	14.9	13.1	14.3	13.3	14.1	12.8	15.3	16.4
Buzzards Bay	16.1	13.2	12.7	12.3	13.8	13.6	15.2	14.1	12.6	12.6	11.5	22.2	18.9

Table 16. Cull rate (percent), by state and region, for marketable American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	8.2	9.9	9.2	13.2	16.2	17.6	14.7	16.0	15.2	15.6	16.1	17.6	17.6
Cape Ann	10.8	9.8	7.3	10.5	20.9	20.7	18.4	19.9	14.0	14.2	16.8	18.1	13.7
Beverly-Salem	4.4	8.0	7.4	15.6	18.5	22.2	17.2	21.3	18.9	23.8	23.1	20.0	24.7
Boston Harbor	---	---	---	10.2	16.2	15.7	12.8	13.1	9.9	9.9	12.4	14.0	17.5
Cape Cod Bay	9.3	9.3	10.0	13.2	15.9	18.2	14.8	15.6	19.1	16.2	17.8	16.7	16.2
Outer Cape Cod	5.3	10.9	8.6	14.8	12.9	16.8	13.2	14.9	13.9	14.6	14.1	16.8	17.3
Buzzards Bay	16.9	13.1	12.3	12.6	15.4	14.1	15.4	14.7	13.0	12.4	11.7	22.5	19.4

Table 17. Cull rate (percent), by state and region, for sub-legal American lobster, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	11.2	11.5	11.6	16.1	20.2	23.2	18.2	19.6	21.1	20.2	19.2	19.3	21.8
Cape Ann	8.0	10.6	12.6	12.2	26.9	28.7	21.5	22.1	17.9	18.3	21.0	18.2	20.9
Beverly-Salem	10.0	9.0	11.2	22.3	24.0	31.8	25.3	28.6	30.8	29.2	31.6	23.5	29.5
Boston Harbor	---	---	---	14.5	20.5	20.0	18.0	18.0	15.2	16.4	13.9	18.3	25.3
Cape Cod Bay	11.9	11.3	11.4	17.0	20.2	23.4	16.8	18.3	24.0	21.8	19.2	19.0	18.8
Outer Cape Cod	7.8	17.9	13.5	11.7	18.6	22.8	11.0	16.9	17.1	20.7	14.3	17.1	20.2
Buzzards Bay	12.7	15.2	12.2	12.4	13.3	14.9	15.0	16.2	12.6	13.9	14.5	18.3	21.0

Table 18. Percent trap mortality by state and region for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1993.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
State	0.15	0.04	0.22	0.15	0.18	0.20	0.10	0.15	0.12	0.17	0.37	0.08	0.13
Cape Ann	0.00	0.00	0.09	0.27	0.03	0.16	0.00	0.03	0.13	0.09	0.48	0.10	0.11
Beverly-Salem	0.00	0.00	0.00	0.00	0.04	0.22	0.03	0.19	0.14	0.29	0.41	0.13	0.19
Boston Harbor	---	---	---	0.00	0.03	0.03	0.23	0.09	0.03	0.04	0.01	0.03	0.06
Cape Cod Bay	0.00	0.02	0.03	0.00	0.00	0.02	0.15	0.00	0.02	0.05	0.02	0.02	0.02
Outer Cape Cod	0.46	0.22	0.23	0.48	0.40	0.85	0.27	0.66	0.47	0.62	0.35	0.24	0.30
Buzzards Bay	0.62	0.00	1.13	0.43	0.76	0.25	0.01	0.18	0.11	0.18	1.74	0.10	0.29

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